Semi-Annual Report for July-December, 2003

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Abstract

The activities of the second half of 2003 were concentrated on quality assurance (Q/A) for our products from the MODIS data stream. We have validated all our MODIS products: Case 2 chlorophyll a algorithms (MOD21), Phytoplankton absorption coefficient at 675 nm, Total Absorption coefficient at 412 nm, Total Absorption coefficient at 443 nm, Total Absorption coefficient at 488 nm, Total Absorption coefficient at 531 nm, and Total Absorption coefficient at 551 nm(MOD 36); Instantaneous photosynthetically available radiation(IPAR), Instantaneous absorbed radiation by phytoplankton for fluorescence(ARP)(MOD22); and Epsilon of clear water aerosols at 531 and 667 nm(MOD39). One peer-reviewed paper is in press and two papers have been accepted for publication. Six symposium papers were submitted to ASLO/TOS Ocean Research conference in Hawaii on February.

Tasks Accomplished Since July 1, 2003

1. Field experiments

a. David English, and Jim Ivey collected remote sensing reflectance, Ed, and water samples for absorption spectra during Tanks II (Sept. 8-12, 2003), Cayo Costa (Nov. 6, 2003), Alafia and Hills (Dec. 5, 8, 9, 2003) experiments. The underway system was also used recording backscattering, gelbstoff florescence, and chlorophyll florescence records which were calibrated and converted to gelbstoff absorption at 400 nm and chlorophyll a.
b. Dan Otis collected remote-sensing reflectance and water samples for absorption spectra on R/V Suncoaster during a West Florida to Mississppi transit experiment from 7/12/03 to 7/22/03. The underway system was also used.

These data will be used to test and adapt the global chlorophyll and CDOM algorithms for presence of bottom-reflected radiance and turbid water in SeaWiFS and MODIS data. The data will also be used for testing our red tide algorithm and for model comparison.

2. Presentations & Symposiums

a. A paper entitled 'KARENIA BREVIS BLOOMS ON THE WEST FLORIDA SHELF: A BRIDGE BETWEEN OPTICS AND PHYSIOLOGY ' by Carder, K.L., Cannizzaro, J.P., Chen, F.R., Heil, C.A., Vargo, G.A was submitted to the Ocean Research conference in Hawaii for presentation in February 2004.

Harmful algal blooms of the ichthyotoxic dinoflagellate, Karenia brevis, regularly occur in the Gulf of Mexico, negatively impacting local tourism and shellfish industries and posing a threat to human health. Mitigation of these adverse effects may be possible if an accurate early detection and bloom monitoring strategy can be developed. Since K. brevis blooms discolor oceanic surface waters, ocean color data may be useful for this purpose. Recently, data collected on the West Florida Shelf as part of the EcoHAB (Ecology and Oceanography of Harmful Algal Blooms) program (1999-2001) indicate that K. brevis blooms are optically unique. When cell concentrations exceeded 10,000 cells per liter, significantly lower chlorophyll-specific particulate backscattering and natural fluorescence were observed relative to high-chlorophyll, diatom-dominated estuarine waters containing fewer than 10,000 cells per liter of K. brevis. Optical techniques developed for classifying and quantifying K. brevis blooms using satellite-based ocean color data from MODIS (Moderate Resolution Imaging Spectrometer) are presented. Also, the effects of physiological strategies of K. brevis (i.e. cellular toxicity and photoadaptation) on developing this unique optical environment are discussed.

b. A paper entitled 'Bathymetry Retrievals From PHILLS Flown Over Turbid Waters' by F.R. Chen, K. L. Carder, R. Steward, J. Ivey, Z. Lee and P. Bissett was submitted to the Ocean Research conference in Hawaii for presentation in February 2004.

Hyperspectral aircraft imagery offers a rapid means of mapping bathymetric changes assuming that the bottom provides at least 15% or so of the signal leaving the water, and the spectral albedo of bottom constituents is known with a reasonable degree of accuracy. For mid-atmospheric (e.g. 10,000 m) imagery of the ocean collected from an aircraft, vibration and thermal stress can change the responsivity of a sensor. To insure that the sensor calibration during the flight is consistent with the solar spectral curve used in the atmospheric-correction code, the sensor should be vicariously calibrated. This contribution applies vicarious calibration and atmospheric correction methodologies to PHILLS hyperspectral aircraft imagery collected by over the dark, turbid waters of Charlotte Harbor, FL. The scenes are then inverted using a genetic algorithm along with a predictor-corrector scheme to derive bottom depth and albedo maps for the vicinity of Caya Costa Key. Bathymetric comparisons with NOAA charts and field data are then discussed. They show that approximately 31 million metric tons of sediment have been eroded from along a 4 km beach front.

c. A paper entitled '3D Simulation of Thermohaline Plumes in the Bahamas' by Hari Warrior and Kendall Carder was submitted to the Ocean Research conference in Hawaii for presentation in February 2004.

Solar energy is incident on the earth's surface in both short-wave and long-wave radiation. The short-wave part of the spectrum is of special interest to oceanographers since the vertical distribution of temperature in the top layer of the ocean is mostly determined by the short-wave radiation. There are numerous studies regarding the temperature evolution as a function of time. We study the diurnal and seasonal variation of the heat content (and hence temperature) of the ocean using various general circulation models in this thesis. The basis for such heat budget simulation lies in the fact that the heat budget is the primary driver of ocean currents (only secondary to wind effects) and these circulation features affect the biological and chemical effects of that region.

The location of the study is the very shallow banks of Bahamas and the negative estuary near Lee Stocking Island. In this thesis, the vertical light attenuation has been simulated by embedding the light models in a 1D model, followed by a 3D turbulence closure model (the Princeton Ocean Model) at the above-mentioned locations.

The main part of the thesis is the inclusion of an optical bottom effect in the shallow waters. The bottom serves two purposes, it reflects some light based on its albedo and it radiates and conducts absorbed light as heat. The heat added from the bottom heat the water column from below convectively overturning it. This intense heating leads to excessive evaporation of these waters leading to hyper-salinity (reaching as high as 45 ppt) in shallow banks regions.1-D simulation including bottom effects clearly indicates the effect of light on the temperature profile and also the corresponding effect on salinity profiles.

An extension of the study includes a 3D simulation of the heat budget and the associated circulation and hydrodynamics. The hyper-saline waters that are formed in the shallow estuary by evaporation advert down to the to depths of 50 m in the summer in Exuma Sound. These plumes have been simulated using a 3D numerical ocean model, and it is consistent with field observations (Hickey, 2000).

d. A paper entitled 'CDOM EFFECTS ON THE UNDERWATER LIGHT FIELD: SIMULATIONS OF ULTRAVIOLET RADIATION INCIDENT UPON CORAL REEFS' by Otis, D.B. and Kendall L. Carder was submitted to the Ocean Research conference in Hawaii for presentation in February 2004.

CDOM (Colored Dissolved Organic Matter) absorbs strongly in the ultraviolet and blue regions of the electromagnetic spectrum and has a strong effect on the underwater light field. Due to it's absorption properties, CDOM protects marine organisms from the harmful effects of UVR (ultraviolet radiation), which has been implicated in the bleaching of reef-building corals and been shown to adversely affect the health of marine organisms. The focus of this study is to estimate dose rates of harmful UVR near various reef sites

worldwide using values of CDOM absorption and chlorophyll concentration obtained from MODIS (Moderate Resolution Imaging Spectroradiometer) data as inputs into the Hydrolight radiative transfer model. Modeled downwelling irradiance values were weighted by the action spectrum of Setlow to estimate biologically-effective doses of UVR at depth. Simulations were done based on three-month means of CDOM absorption and chlorophyll concentration to examine seasonal variability

e. A paper entitled 'LARGE-SCALE, MULTI-CHANNEL VIDEO MOSAICS OF A CORAL REEF AUTOMATICALLY CONSTRUCTED FROM IMAGERY ACQUIRED USING AN AUTONOMOUS UNDERWATER VEHICLE' by *Weilin Hou, K. L. Carder, D. K. Costello, D. C. English* was submitted to the Ocean Research conference in Hawaii for presentation in February 2004.

Large-scale mosaic images were created from individual video frames obtained from three, narrow-band video channels (460, 520 and 575nm) acquired using a multi-channel, intensified video camera (Xybion IMC-301) onboard the autonomous underwater vehicle (AUV) ROVEX during the CoBOP 2000 field campaign. The pseudo-colored mosaics of a spur-and-grove coral region approximately 3.5x36 m^2 near Lee Stocking Island, Bahamas, will not only help to identify coral on the ocean floor, but also provide detailed stereographic bathymetric information over the sampled area that, because of the complex topography of the scene, is superior to even precision acoustic bathymetry. The approach is based entirely on scene-content-tracking and allows automatic construction of continuous mosaics for each channel. The effects of wave focusing on the imagery and the future inclusions of a solar-stimulated bottom fluorescence channel (685 nm) are also discussed.

f. A paper entitled 'VARIATION OF PIGMENT COMPOSITION IN RESPONSE TO LIGHT QUALITY' by Malick, L.A, Carder, K.L, Cannizzaro, J.P., Ivey, J.E., was submitted to the Ocean Research conference in Hawaii for presentation in February 2004.

We present a method using calculations of the underwater light field to predict/describe phytoplankton pigment composition at depth. Our results allow us to examine how changes in water column constituents that alter the underwater light field, may affect the composition and function of phytoplankton pigments at depth. We identified stations from various cruises off the West Florida Shelf that exhibited extremes in chlorophyll and/or CDOM concentration. Optical and water column constituent measurements from these stations were used to develop input parameters to Hydrolight 4.1, a radiative transfer theory model, to simulate the underwater light field. Specific phytoplankton absorption spectra were deconvolved into pigment groups at depth, allowing us to examine how changes in water column constiuents affect

pigment composition, and what this indicates about pigment adaptation to the existing light field.

3. Peer-reviewed Publications

a. A paper entitled **'**Performance of the MODIS Semi-Analytical Ocean Color Algorithm FOR Chlorophyll-*a'* by K.L. Carder, F.R. Chen, J.P. Cannizzaro, J.W. Campbell, and B.G. Mitchell has been pressed in the Advances & Space Research.

The Moderate Resolution Imaging Spectroradiometer (MODIS) semi-analytical (SA) algorithm calculates the spectral absorption properties of surface waters, splitting them into those associated with phytoplankton, $a_{ph}(\_)$, colored dissolved organic matter or gelbstoff, $a_g(\_)$, and water, $a_w(\_)$. The phytoplankton absorption coefficient, $a_{ph}(675)$, is then used to derive the concentration of chlorophyll-*a*, Chlor_a_3. The SA algorithm is designed to respond to variable ratios of $a_{ph}(\_)$ to $a_g(\_)$ and to wide ranges in the chlorophyll-specific phytoplankton absorption coefficient, $a^*_{ph}(\_)$, for a given chlorophyll-*a* level. In this paper, the SA algorithm is expanded to include environments consistent with strong upwelling zones and high latitudes. Spatial and temporal differences in MODIS Terra chlorophyll-*a* retrievals are examined between Chlor_a_3 and an empirical algorithm, Chlor_a_2, developed to mimic the performance of the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) OC-4 chlorophyll-*a* algorithm. The greatest differences observed are for upwelling regions and for southern high-latitude waters during austral spring where Chlor_a_2 values are on average about half of field and Chlor_a_3 values due to lower chlorophyll-specific phytoplankton absorption coefficients typical of this region. Preliminary match-up results indicate strong linearity and good agreement between *in situ* chlorophyll-*a* concentrations and MODIS-derived Chlor_a_3 compared to Chlor_a_2.

b. A paper entitled "A novel technique for detection of the toxic dinoflagellate**,** ***Karenia brevis*,** Jennifer P. Cannizzaro*, Kendall L. Carder, F. Robert Chen, Cynthia A. Heil, and Gabriel A. Vargo has been accepted for publication in the *Continental Shelf Research* EcoHAB special issue in June 2003

Karenia brevis, a toxic dinoflagellate species that blooms regularly in the Gulf of Mexico, frequently causes widespread ecological and economical damage to coastal communities. Between 1999 and 2001, a large bio-optical data set consisting of remote-sensing reflectance, absorption, and backscattering spectral measurements and chlorophyll *a* concentrations was collected on the central West Florida Shelf as part of the EcoHAB (Ecology and Oceanography of Harmful Algal Blooms) and HyCODE (Hyperspectral Coupled Ocean Dynamics Experiment) programs. Model simulations indicate that absorption due to phytoplankton, detritus, and gelbstoff cannot account for the factor of 3 to 4 decrease in remote-sensing reflectance spectra, $R_{rs}(\lambda)$, observed in waters containing greater than 10^4 cells l^{-1} of *K. brevis*. Chlorophyll-specific particulate backscattering coefficients, $b^*_{bp}(\lambda)$, measured inside *K. brevis* blooms, though, were significantly lower than values

measured in high-chlorophyll estuarine waters, typically dominated by diatoms. Since deviations in $b^*_{bp}(\lambda)$ can explain the observed decrease in $R_{rs}(\lambda)$ according to model simulations, a classification technique for identifying waters containing greater than 10^4 cells l^{-1} of *K. brevis* is developed based on these results. In addition, a method for quantifying chlorophyll concentrations in *K. brevis* blooms using fluorescence line height (FLH) data is introduced. The classification technique is successfully applied to SeaWiFS (Sea-viewing Wide Field-of-view Sensor) data acquired in late August 2001 and validated using *in situ K. brevis* cell concentrations. All stations containing greater than 10^4 cells l^{-1} of *K. brevis* were successfully flagged using this technique.

c. A paper entitled 'CDOM Transport from the Bahamas Banks' Otis D.B., Carder K.L., English D.C., Ivey J.E. has been accepted for publication in **Coral Reefs *Vol 23, No. 1 2004***

The transport of colored dissolved organic matter (CDOM) between shallow banks and deep basins in the Bahamas was the focus of this study. Hydrographic and CDOM absorption measurements made on the Bahamas Banks and in Exuma Sound during the spring of 1999 and 2000 showed that values of salinity and CDOM absorption at 440nm were higher on the banks (37.18psu, $0.06m^{-1}$), compared to Exuma Sound (37.04psu, $0.03m^{-1}$). Spatial patterns of CDOM absorption in Exuma Sound revealed that plumes of CDOM-rich water flow into Exuma Sound from the surrounding banks. These patterns were determined using Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data processed using a Moderate Resolution Imaging Spectroradiometer (MODIS) algorithm to derive CDOM absorption estimates. These data, along with time-series data collected in a channel between the banks and sound, suggest that bank water rich in CDOM and salinity leaves the banks during ebb tide, while sound water, with lower levels of CDOM and salinity, extends onto the banks during flood tide. Since CDOM absorbs ultraviolet radiation, a causal factor of reef organism bleaching, we discuss the meaning of our findings in terms of susceptibility to coral bleaching in the Exuma region.